IS 1528-22 (2007): Methods of Sampling and Physical Tests for Refractory Materials, Part 22: Methods for Determination of Permeability to Gases of Dense Shaped Refractoy Products [MTD 15: Refractories]

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भारतीय मानक

उष्मासह सामग्रियों के नमूने लेने की और भौतिक परीक्षण पद्धतियाँ

भाग 22 सघन आकारित अग्निसह उत्पाद की गैस पारगम्यता ज्ञात करने की पद्धति

Indian Standard

METHODS OF SAMPLING AND PHYSICAL TESTS FOR REFRACTORY MATERIALS

PART 22 METHOD FOR DETERMINATION OF PERMEABILITY TO GASES OF DENSE SHAPED REFRACTORY PRODUCTS

ICS 81.080

BUREAU OF INDIAN STANDARDS
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NEW DELHI 110002

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Price Group 3

NATIONAL FOREWORD

This Indian Standard (Part 22) which is identical with ISO 8841 : 1991 'Dense, shaped refractory products — Determination of permeability to gases' issued by the International Organization for Standardization (ISO) was adopted by the Bureau of Indian Standards on the recommendation of the Refractories Sectional Committee and approval of the Metallurgical Engineering Division Council.

The text of ISO Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker, while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards, which are to be substituted in their places, are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
ISO 6906 : 1984 Vernier calipers reading to 0.02 mm	IS 3651 (Part 2) : 1985 Specification for vernier calipers: Part 2 Vernier calipers with least count 0.02 mm (*second revision*)	Technically Equivalent
ISO 5022 : 1979 Shaped refractory products — Sampling and acceptance testing	IS 1528 (Part 7) : 1974 Methods of sampling and physical tests for refractory materials: Part 7 Methods of sampling and criteria for conformity (*first revision*)	do

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

METHODS OF SAMPLING AND PHYSICAL TESTS FOR REFRACTORY MATERIALS

PART 22 METHOD FOR DETERMINATION OF PERMEABILITY TO GASES OF DENSE SHAPED REFRACTORY PRODUCTS

1 Scope

This International Standard specifies a method for the measurement of the permeability to gases of dense, shaped refractory products.

NOTE 1 The method specified takes account of the dynamic viscosity of the gas, and therefore the results obtained may not be directly comparable with those obtained by earlier methods which took no account of viscosity. The determination is generally made by the passage of air. Other gases may be used when required, and the viscosities of air and nitrogen are given.

2 Normative reference

The following standard contains provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 6906:1984, *Vernier callipers reading to 0,02 mm.*

3 Definition

For the purposes of this International Standard, the following definition applies.

3.1 permeability of a material: The property by which the material allows a gas to pass through it when under a difference of pressure.

The permeability (μ) is calculated using the following equation, given for the volume of gas passing through a test piece in a given time:

$$\frac{V}{t} = \mu \cdot \frac{1}{\eta} \cdot \frac{A}{\delta} \cdot (p_1 - p_2) \cdot \frac{(p_1 + p_2)}{2p} \qquad \ldots (1)$$

where

V is the volume of gas passing through the material, in cubic metres;

t is the time, in seconds, in which that volume of gas passes through the material;

μ is the permeability of the material, in square metres;

η is the dynamic viscosity, in pascal seconds, of the gas at the temperature of the test;

A is the cross-sectional area, in square metres, of the material traversed;

δ is the thickness, in metres, of the material traversed;

p is the absolute pressure, in pascals, of the gas;

p_1 is the absolute pressure, in pascals, where the gas enters the material;

p_2 is the absolute pressure, in pascals, where the gas leaves the material.

NOTES

2 Equation (1) corresponds to Darcy's Law, and is deduced from the Hagen Poiseuille Law.

3 Since p is the pressure under which the volume of gas is measured, $p = p_1$ when operating under positive pressure, and $p = p_2$ when operating under negative pressure.

4 The factor $(p_1 + p_2)/2p$ is usually very close to unity and may be neglected when operating with small pressure differences, e.g. when $(p_1 - p_2)$ is less than 1 000 Pa.

Equation (1) may be rearranged as

$$\mu = \frac{V}{t} \cdot \eta \cdot \frac{\delta}{A} \cdot \frac{1}{p_1 - p_2} \cdot \frac{2p}{p_1 + p_2} \qquad \ldots (2)$$

Writing equation (2) in the units involved, the unit for permeability is square metres, derived from

$$\frac{\text{m}^3}{\text{s}} \cdot \text{Pa} \cdot \text{s} \cdot \frac{\text{m}}{\text{m}^2} \cdot \frac{1}{\text{Pa}} \cdot \frac{\text{Pa}}{\text{Pa}}$$

If, in equation (1), δ is expressed in centimetres, A in square centimetres and V in cubic centimetres (the units for the other quantities being unchanged), an alternative unit for permeability may be derived, namely square centimetres. However, since compound prefixes are not permissible, the conventional prefixes may be used only with the unit square metres, thus $10^{-8}\ \text{cm}^2 = 10^{-12}\text{m}^2 = 1\mu\text{m}^2$.

4 Principle

A stream of dry gas is passed through the test piece, and the pressure drop across the test piece is recorded for at least three different rates of flow. From these values, and from the size and shape of the test piece, the permeability of the material is determined by calculation.

5 Apparatus

5.1 General

The general layout of the apparatus is shown diagramatically in figures 1 and 2. Figure 1 shows the arrangement for the passage of gas under pressure and figure 2 for the passage of gas under suction. The connecting piping shall be made of glass in preference to rubber, and shall be as short as possible, so that the pressure loss in the apparatus is very small when compared with the pressure loss produced by the test piece.

5.1.1 Supply of gas (under pressure or suction), consisting of a reservoir of gas at constant pressure.

5.1.2 Test piece holder, with gas-tight seals at the sides of the test piece. Gas tightness shall be ensured by a rubber membrane that is inflated to a pressure of 0,2 N/mm^2 to 0,4 N/mm^2. See figure 3.

NOTE 5 Modifications will be required if the alternative test piece size (see note to 6.1) is used.

5.1.3 Liquid manometer, of the U-tube type, for measuring the difference in pressure between the two faces of the test piece. The usual experimental precautions for this type of measurement shall be taken, so that the error in the pressure determination does not exceed 1 % (including error in reading column height, meniscus error, error in the verticality of the manometer, and measurement of the density of the manometer liquid). The pressure shall be determined close to one face of the test piece in the vessel containing the test piece holder (5.1.2).

NOTE 6 A lower pressure reading may result when the pressure away from the test piece is determined in the connecting tubes.

5.1.4 Gas flow measuring equipment, consisting of a sensitive floating flowmeter calibrated for a given temperature and pressure of entry. The flowmeter shall be accurate to within 2 %. The flowmeter shall be calibrated periodically for the gas to be used, and only the middle section of its measuring scale shall be used.

For the measurement of permeability to air only, the rate of air flow is measured by the displacement of air by water, using a graduated cylinder device and a chronometer.

5.1.5 Vernier callipers, in accordance with ISO 6906.

5.1.6 Drying oven, capable of being controlled at 110 °C ± 5 °C.

5.1.7 Impermeable dummy test piece, for example an aluminium cylinder.

6 Test pieces

6.1 Dimensions

The test pieces shall be cylindrical, with diameter 50 mm ± 0,5 mm and height 50 mm ± 0,5 mm. The perpendicularity of the axis of the test piece to the faces, and the parallelism between the top and bottom faces of the test piece shall both be within 0,5 mm.

NOTE 7 A 50 mm cube test piece may also be used where necessary. In this case the test piece holder (see note to 5.1.2) will need to be modified and the calculation of the results (see 8.3) will be slightly different.

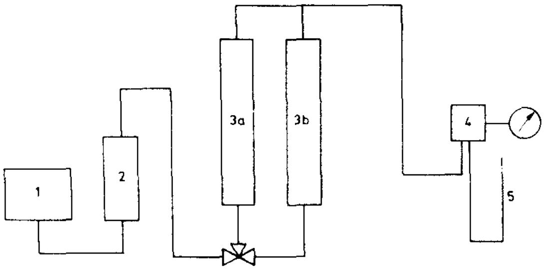
6.2 Preparation

The test pieces shall be cut in such a way that no material is included that was within 4 mm of a face of the brick or item. The direction in which the test pieces are cut, relative to the direction of pressing, shall be stated in the test report.

The faces shall be freed from dust formed during the cutting, by brushing under a jet of water following wet cutting, or by a jet of compressed air following dry cutting.

6.3 Drying

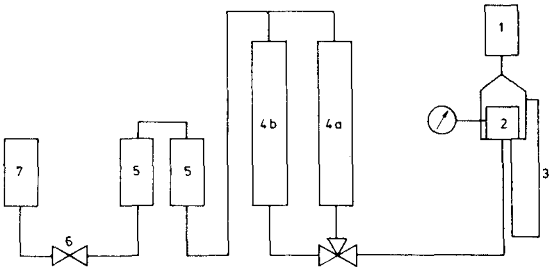
The test pieces shall be dried to constant mass in the drying oven (5.1.6) at 110 °C ± 5 °C. Before measurement, the test pieces shall be allowed to cool to room temperature in a desiccator; the time of cooling shall be at least 2 h.



KEY

1 Source of gas (compressed gas cylinder or water reservoir)
2 Desiccator for the gas
3 Floating flowmeters: (a) 0 to 200 cm^3/min, (b) 200 cm^3/min to 1 500 cm^3/min
4 Holder for cylindrical sample
5 U-tube manometer, filled with liquid

Figure 1 — Arrangement of instruments for measuring gas permeability (measured under a pressure head)



KEY

1 Entry of the gas, via a desiccator
2 Holder for cylindrical sample
3 U-tube manometer filled with liquid
4 Floating flowmeters: (a) 0 to 200 cm^3/min, (b) 200 cm^3/min to 1 500 cm^3/min
5 Woulff safety bottles
6 Regulating vent
7 Diaphragm or water pump

Figure 2 — Arrangement of instruments for measuring gas permeability (measured under suction)

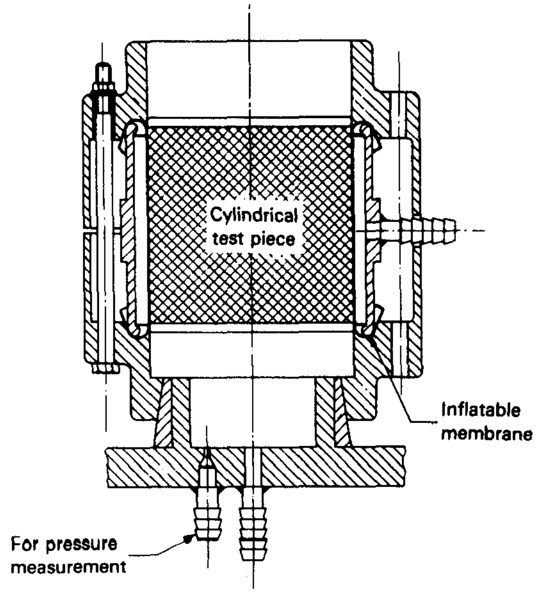


Figure 3 — Test piece holder

7 Procedure

7.1 Carry out a blank determination to establish that the test rig is gas-tight using an impermeable dummy test piece (5.1.7) in the place of the normal test piece.

7.2 Measure the diameter and the height of the test piece to 0,1 mm, using the Vernier callipers (5.1.5).

7.3 Place the test piece in the holder (5.1.2), ensuring that the pressure on the rubber membrane is sufficient to render the cylindrical surface of the test piece gas-tight. This may be checked by increasing the pressure on the membrane; there should be no change in the pressure difference between the plane faces and no change in the rate of gas flow.

7.4 Determine the rate of flow through the test piece for at least three different pressure drops across it. Calculate the permeability of the test piece for each determination. (See clause 8.)

NOTE 8 These determinations are to verify that the rate of flow is proportional to the pressure drop, because the equation used for the calculation (see clause 8) is only valid for laminar flow.

7.5 If the calculated permeabilities at the three different pressure drops differ among themselves by more than 5 %, repeat the blank test, check the equipment and repeat the tests. If the repeat tests still differ by more than 5 %, state this in the test report.

8 Expression of results

8.1 The permeability, expressed in square metres to two significant digits, is given by the equation

$$\mu = \eta \cdot \frac{h}{A} \cdot \frac{1}{\Delta p} \cdot q_V \cdot k_v \qquad \ldots (3)$$

where

η is the dynamic viscosity, in pascal seconds[1], of the gas passed through the test piece at the temperature of the test;

h is the height, in metres, of the test piece;

A is the cross-sectional area, in square metres, of the test piece through which the gas has passed (see 7.2);

Δp is the pressure difference across the test piece, in pascals;

q_V is the rate of flow, in cubic metres per second, of gas through the test piece;

k_v is a correction factor (see table 1) for the removal of water vapour (used only if the air flow was measured by displacement of water).

NOTE 9 For air temperatures from 16 °C to 24 °C the values for the dynamic viscosity of air (η) are given in table 1, and these may be used under the assumption that the pressure drop over the test piece is small (see note 3 to clause 3). The values for the dynamic viscosity of nitrogen are given in table 2, from 10 °C to 35 °C.

8.2 Equation (3) may be written in terms of the units more likely to be directly read in the test. Thus the value of the permeability, expressed in square centimetres, is given by

$$\mu = \eta \cdot \frac{h}{10^3} \cdot \frac{4 \times 10^6}{\pi d^2} \cdot \frac{1}{9{,}807 \Delta p'} \cdot \frac{q'_V}{60 \times 10^6} \times 10^4$$

$$= \frac{2{,}16 \times 10^{-2} \eta h q'_V}{d^2 \Delta p'} \cdot k_v \qquad \ldots (4)$$

where

η is the dynamic viscosity, in pascal seconds, of the gas passed through the test piece at the temperature of the test;

h is the height, in millimetres, of the test piece;

d is the diameter, in millimetres, of the test piece;

$\Delta p'$ is the pressure difference across the test piece, in millimetres, of water column[2];

q'_V is the rate of flow, in cubic centimetres per minute, of gas through the test piece;

k_v is a correction factor (see table 1) for the removal of water vapour (used only if the air flow was measured by displacement of water).

8.3 If the alternative test piece size and holder is used (see 6.1 and 5.1.2), equation (4) will be modified as follows:

$$\frac{4 \times 10^6}{\pi d^2} \text{ is replaced by } \frac{10^6}{x^2}$$

where x is the side, in millimetres, of a cubic test piece. Equation (4) becomes

$$\frac{1{,}70 \times 10^{-2} \eta h q'_V}{x^2 \Delta p'} \cdot k_v$$

Table 1 — Dynamic viscosity of air

Temperature °C	Dynamic viscosity $\times 10^{-6}$ Pa·s	k_v
16	17,88	0,982
18	17,98	0,980
20	18,08	0,911
22	18,18	0,914
24	18,28	0,971

1) 1 poise = 0,1 Pa·s

2) 1 mmH$_2$O = 9,807 Pa

Table 2 — Dynamic viscosity of nitrogen

Temperature °C	Dynamic viscosity × 10^{-6} Pa·s	Temperature °C	Dynamic viscosity × 10^{-6} Pa·s
10	17,1	23	17,7
11	17,2	24	17,8
12	17,2	25	17,8
13	17,3	26	17,9
14	17,3	27	19,9
15	17,4	28	18,0
16	17,4	29	18,0
17	17,5	30	18,1
18	17,5	31	18,1
19	17,6	32	18,2
20	17,6	33	18,2
21	17,7	34	18,2
22	17,7	35	18,3

9 Test report

The test report shall include the following information:

a) the name of the testing establishment;

b) the date of the test;

c) a reference to this International Standard, i.e. "Determined in accordance with ISO 8841";

d) a description of the material tested (manufacturer, type, batch number, etc.);

e) the number of samples tested for each direction of gas flow in the brick or item;

f) the gas used;

g) the separate pressure drops (pressure or suction) across the test piece, and the corresponding rate of gas flow through the test piece;

h) the mean value of the permeability of the material for each direction of gas flow (relative to the direction of pressing of the brick or item);

i) reference to any variation in permeability between the three different determinations which is greater than the permitted value (see 7.4 and 7.5).

NOTE 10 The individual values are used for determining the mean value. The mean value is used for further statistical analysis, in accordance with the ISO 5022.

Bureau of Indian Standards

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Review of Indian Standards

Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the latest issue of 'BIS Catalogue' and 'Standards: Monthly Additions'.

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Amendments Issued Since Publication

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